# Survival and mortality of protected and non-protected *Juniperus ashei* seedlings in Central Texas juniper/live oak woodlands

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## ABSTRACT

*Juniperus ashei* is a dominant woody species in many Central Texas woodlands on the Edwards Plateau. It readily encroaches into disturbed grasslands. Past studies of one cohort of *J. ashei* seedlings below a *J. ashei* canopy projected extinction in 35 y with none reaching the canopy. However, effects of herbivory have not been examined previously. Mortality of *J. ashei* seedlings protected from herbivory (caged) or not protected (not caged) was investigated. The study site was in the Albert and Bessie Kronkosky State Natural Area (under development) in the Central Texas Edwards Plateau physiographic region (N 29.74619°, W 98.83573°). Treatments compared 50 caged *J. ashei* seedlings and 50 non-caged seedlings. All *Juniperus ashei* seedlings had just emerged and were selected arbitrarily from the *J. ashei* understory. Cages were cylindrical, 30 cm tall and 15 cm wide, constructed of 1.3 cm galvanized hardware cloth, anchored with rebar. The seedlings were counted bi-weekly the first growing season then annually. Seedlings with any green foliage present were considered alive. Three caged seedlings and four non-caged seedlings died in year one (2019). There was no significant difference in mortality between caged and non-caged seedlings in year one ($X^2$=0.154, $P > 0.05$). Mortality continued through year five of the study linearly with no significant difference between treatments. Mortality was 50 % (25 plants) for protected juveniles and 58 % (29 plants) for non-protected juveniles at the end of the fifth growing season ($X^2$=0.644, $P$ = 0.422). Herbivory is not important for juvenile *J. ashei* survival. *Published online* ***www.phytologia.org*** *Phytologia 105(3): 84-90 (December 21, 2023). ISSN 030319430.*

**KEY WORDS:** herbivory, caged plants, non-caged plants, survival, replacement, recruitment, lack of recruitment, Edwards Plateau

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Species recruitment is controlled by biotic and abiotic factors or a combination of both (Keddy 2017; Begon and Townsend 2021). Common as well as rare species are affected similarly (Falk et al. 1996; Poole et al. 2007; Nelson-Dickerson and Van Auken 2016; Van Auken et al. 2022, 2023). Factors could include water availability, other soil resources, light levels, herbivory, and a species' competitive abilities. Controlling factors can have positive, negative or mixed effects on a given species. Herbivore browsing can be detrimental and a major contributor to seedling mortality and lack of recruitment (Ameztegui and Coll 2015; Van Auken et al. 2022, 2123). *Juniperus ashei* seedlings have been shown to survive for 35 years beneath *J. ashei* cover, but none reached the canopy (Van Auken et al. 2004). Although *J. ashei* is a dominant woody plant in many Central Texas Edwards Plateau woodlands communities, there is some recruitment in open areas associated with the woodland canopies (McKinley and Van Auken 2005; Van Auken et al. 2023). However, the importance of herbivory to recruitment of juvenile *J. ashei* plants has not been examined.

There are other woody species found in these Edwards Plateau woodlands (Van Auken 2008). Some of the other woody species include *Diospyros texana* (Texas persimmon), *Prosopis glandulosa* (honey mesquite), *Sephora secundiflora* (mountain laurel), *Acer grandidentatum* (bigtooth maple), *Quercus lacyi* (Lacy oak), *Q. muehlenbergii* (chinkapin oak), *Juglans major* (Texas black walnut), and others (Van Auken et al. 2022). Many juveniles of these species are present in the understory of these communities with little

or no recruitment into the overstory (Van Auken et al. 2023).

*Juniperus ashei* seedling mortality is related to multiple variables, including temperature, rainfall, canopy cover, soil moisture, and light availability (Jackson and Van Auken 1997; Van Auken et al. 2004; McKinley and Van Auken 2005). In addition, fire and herbivory are important for recruitment of many species (Collins and Wallace 1990; Cote et al. 2004; Andruk et al. 2014). Previous studies demonstrated that *J. ashei* seedling emergence was greatest one to four months after higher rainfall during the coldest months (Van Auken et al. 2004) and most mortalities occurred during months that were hot and dry (Jackson and Van Auken 1997). Lowest mortality was in the *J. ashei* understory (Jackson and Van Auken 1997). Seedling mortality was approximately 8% per year, but the cause of mortality was not determined (Van Auken et al. 2004). Some have examined effects of herbivory on different *Juniperus* species (Cadenasso et al. 2002), while herbivory of mature *J. ashei* has been observed (Armstrong and Young 2002; Bryant et al. 1981; Warren 1983), it was a minor part of the ungulates diet and apparently did not include juveniles.

The relationship between large herbivores and *J. ashei* seedling mortality is inferred but not well studied. Most of the *J. ashei* herbivory studies look at *Odocoileus virginianus* (white-tailed deer) as the main herbivore (Armstrong and Young 2002). *Juniperus ashei* is infrequently browsed, and *O. virginianus* prefer other species including various *Quercus spp., Ulmus spp.* (elm), *Celtis spp.* (hackberry), and *Eysenhardtia texana* (Texas kidneywood). *Juniperus ashei* browsing is an indicator of poor range conditions and low availability of more favorable forage (Armstrong and Young 2002). *Juniperus* foliage and mast in a range with poor conditions (Bryant et al. 1981) was between 17-26% (Warren 1983).

The purpose of this study was to examine survival and mortality of *J. ashei* seedling that were protected from herbivory caused by large herbivores (caged) or unprotected, in the open (non-caged).

## MATERIALS AND METHODS

This study was conducted on the Albert and Bessie Kronkosky State Natural Area (ABK, under development, not open to the public) approximately 14 km west of Boerne, Texas, within the Edwards Plateau Physiographic Region (Fig. 1). The natural area is approximately 1500 ha. The study site was below a mature *J. ashei* canopy (29.74589°N, 98.83710°W). The elevation was approximately 470 m above sea level. The mean annual temperature was approximately 18.94 °C, and the mean annual precipitation was approximately 79.35 cm with considerable variability (NOAA 2019). The soil type is a mixture of the Krum and Pratley series. The Krum series formed in clayey limestone alluvium. The Pratley series formed as a pedisediment from limestone bedrock (Soil Survey Staff 2014). The Edwards Plateau region of Texas has one of the highest populations of *Odocoileus virginianus* (white-tailed deer) in North America (Russell et al. 2001; Russell and Fowler 2004; Van Auken 2018), but the natural area is high fenced with a reduction in the *O. virginianus* population (Carpenter and Brandimarte 2014).

Finding and identifying *J. ashei* seedlings was carried out from May-July 2019. Seedlings were selected arbitrarily from the *J. ashei* understory for inclusion in the study with an example of a living and dead seedling in Fig. 2. All seedlings were current year germinates with cotyledons (two opposite, long seed leaves). Sample seedlings were tagged with 3 cm round stainless-steel tags numbered 1 through 100. The tags were secured with 15 cm long, 0.2 cm diameter, galvanized steel garden staples.

The exclosures were constructed using 1.3 cm galvanized hardware cloth and 0.1 cm galvanized steel wire and some of the exclosures below the canopy are shown in Fig. 3. The hardware-cloth was cut into 30 x 47 cm rectangles, rolled into a 30 cm tall cylinder, and edges were secured with 3 pieces of 8 cm long wire. The hardware cloth was also cut into 18 cm by 18 cm squares to secure the top of the cylinders. The exclosures were installed over 50 seedlings (tagged with even numbers) and secured to the ground with

3 pieces of approximately 1 cm by 61 cm rebar. All of the seedlings (protected and non-protected) were observed biweekly from July 2019 through November 2019 of the first growing season. After the first year they were examined annually in late summer. A seedling was considered alive if any green foliage was present. A chi-squared test was performed to compare the seedling mortality between the caged and non-caged treatments.

On November 19, 2019, at mid-day, light levels were measured using a FieldScout Quantum Light Monitor 3415F. Twenty light measurements were made in an open area with ambient light, in addition to 20 measurements made adjacent to 20 samples in cages and 20 in the open (no cage) all in the *J. ashei* understory. A one-way analysis of variance (ANOVA) and Tukey-Kramer Multiple Range Test were used to compare the mean light levels between the understory caged and non-caged, plants as well as open ambient light measurements. In addition, number of surviving plants or mortalities in various treatments at various times were examined with non-parametric $X^2$ analyses in JMP Pro 16.

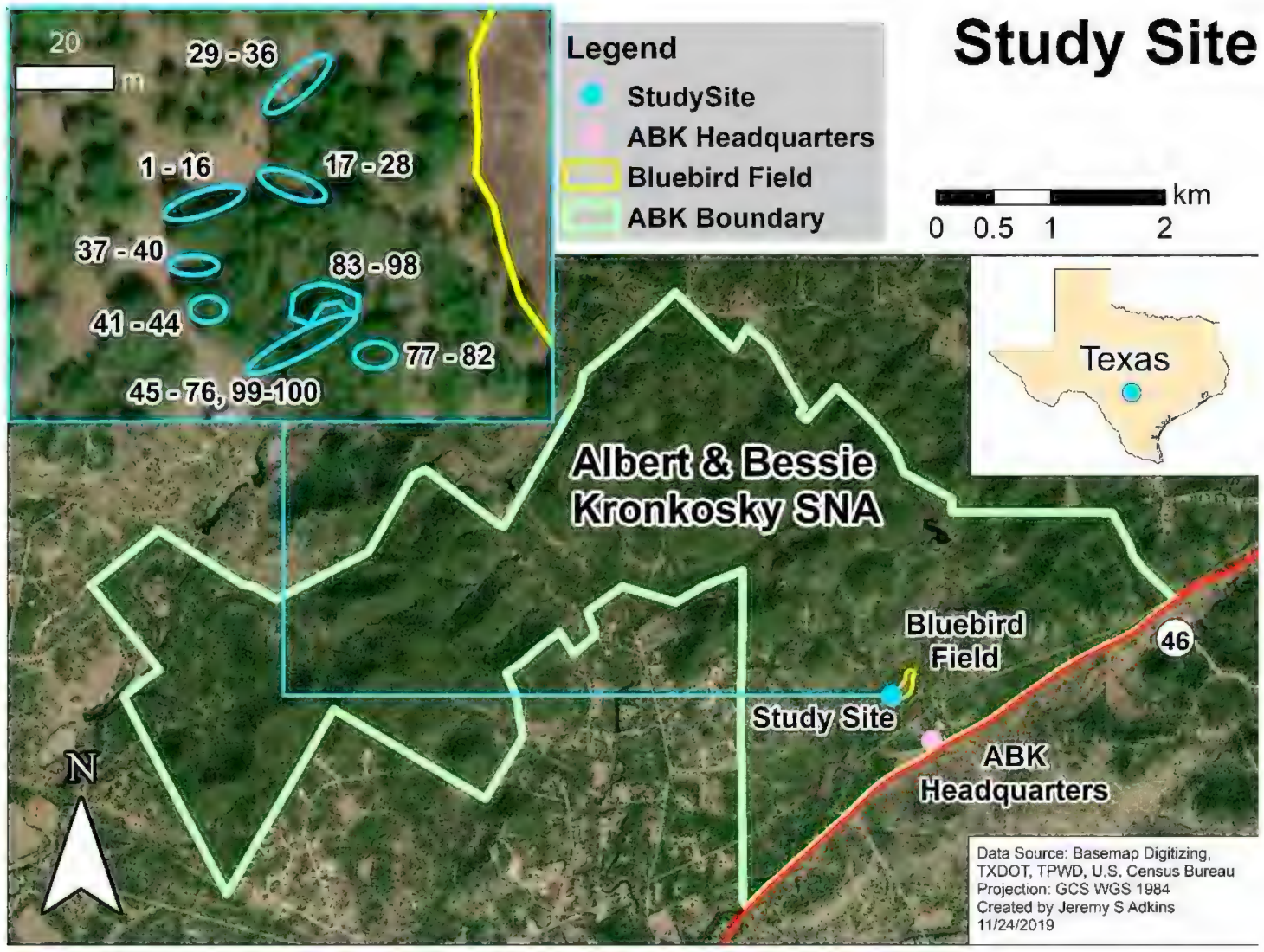


Figure 1. Map of the study site showing the approximate location in Texas (upper right) and in The Albert and Bessie Kronkosky State Natural Area (lower right). The natural area boundary and the approximate distribution of seedling samples throughout the study site. The natural area is located along Texas State Highway 46 in Bandera and Kendall Counties (lower right). The study site is in Bandera County.


Figure 2. Comparison of a live *Juniperus ashei* seedling (A) and a dead *J. ashei* seedling (B). A seedling was considered alive if any green tissue was present.

Figure 3. *Juniperus ashei* understory showing seedling exclosures (with seedlings), and the shade variability present in parts of the study area.

## RESULTS

At the end of the first growing season (November 2019) 47 protected *J. ashei* seedlings were alive (3 dead), and 46 unprotected, open (non-caged) *J. ashei* seedlings were alive (4 dead). There was no significant difference between treatments ($X^2$=0.154, $P > 0.05$). All mortalities occurred during the summer of the first year (Fig. 4A and B).

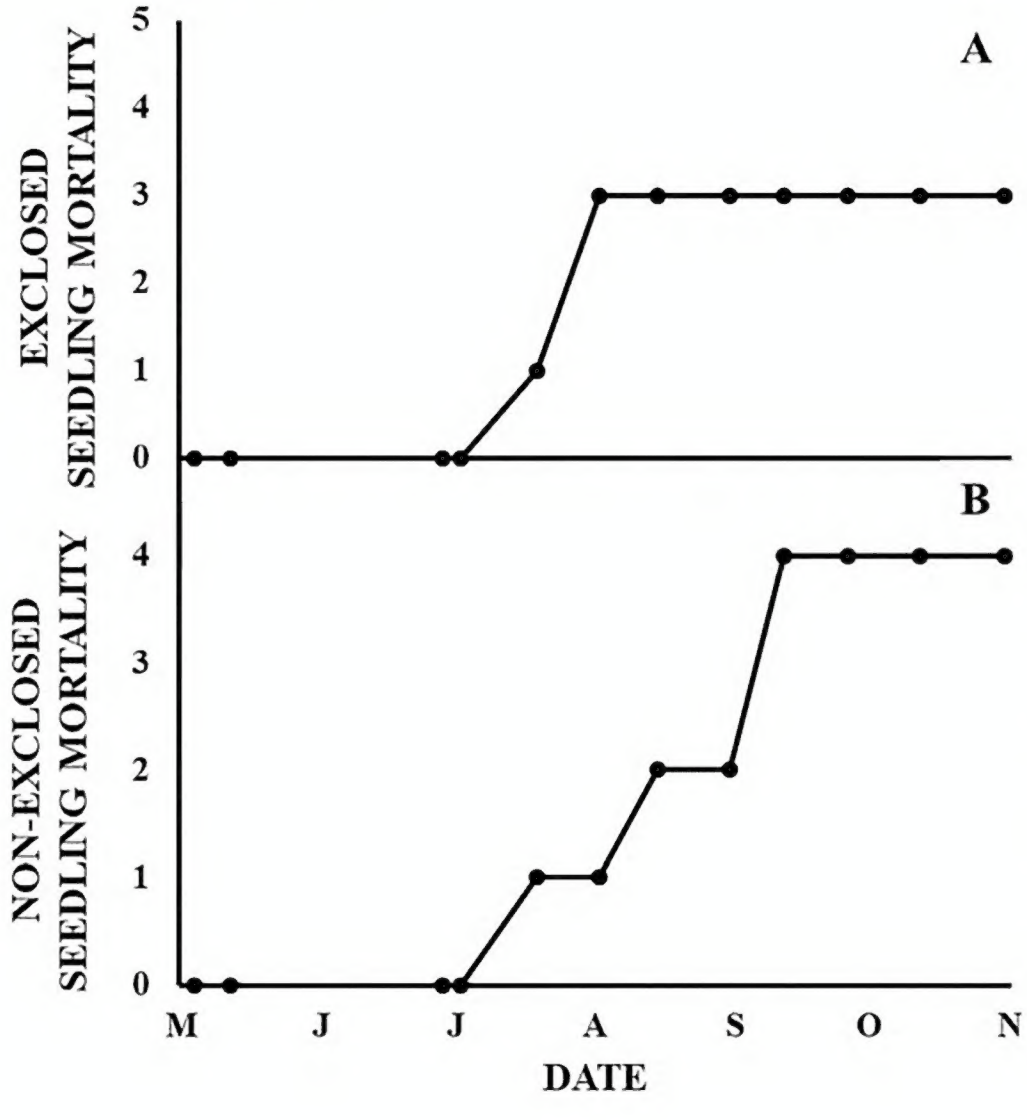


Figure 4. Seedling mortality of *Juniperus ashei* seedlings at Albert and Bessie Kronkosky State Natural Area between May 23, 2019 and November 19, 2019. (A) Of the 50 tagged and caged *J. ashei* seedlings, 3 died. (B) Of the 50 tagged and non-caged *J. ashei* seedlings, 4 died. There is no difference between caged and non-caged seedlings ($X^2$=0.154, $P > 0.05$).

The mean light level was 198 ± 323 µmol·m$^{-2}$s$^{-1}$ for understory cage treatments and 329 ± 383 µmol·m$^{-2}$s$^{-1}$ for open, non-caged plants. The mean understory light level was 263 ± 365 µmol·m$^{-2}$s$^{-1}$ and in the open outside the canopy it was 1521 ± 72 µmol·m$^{-2}$s$^{-1}$ (November 19, 2019, Table 1). There was no significant difference between the mean understory caged versus non-caged treatments ($p>0.05$). There was a significant difference between the mean open ambient (no canopy) light levels and the mean understory light levels ($p<0.01$).

Seedling mortality continued to increase for protected and non-protected individuals through the fifth year of the study. For the open plants (non-caged) there were 29 total mortalities (58% of the total). While for the protected plants (caged) there were 25 total mortalities (50% of the total) with no significant differences (Fig. 5, $X^2$=0.645, $P$ = 0.422). There were 21 survivors in the open and 25 in the protected treatments (Fig. 5). Most mortalities were in the last two years of the study (Fig. 5).

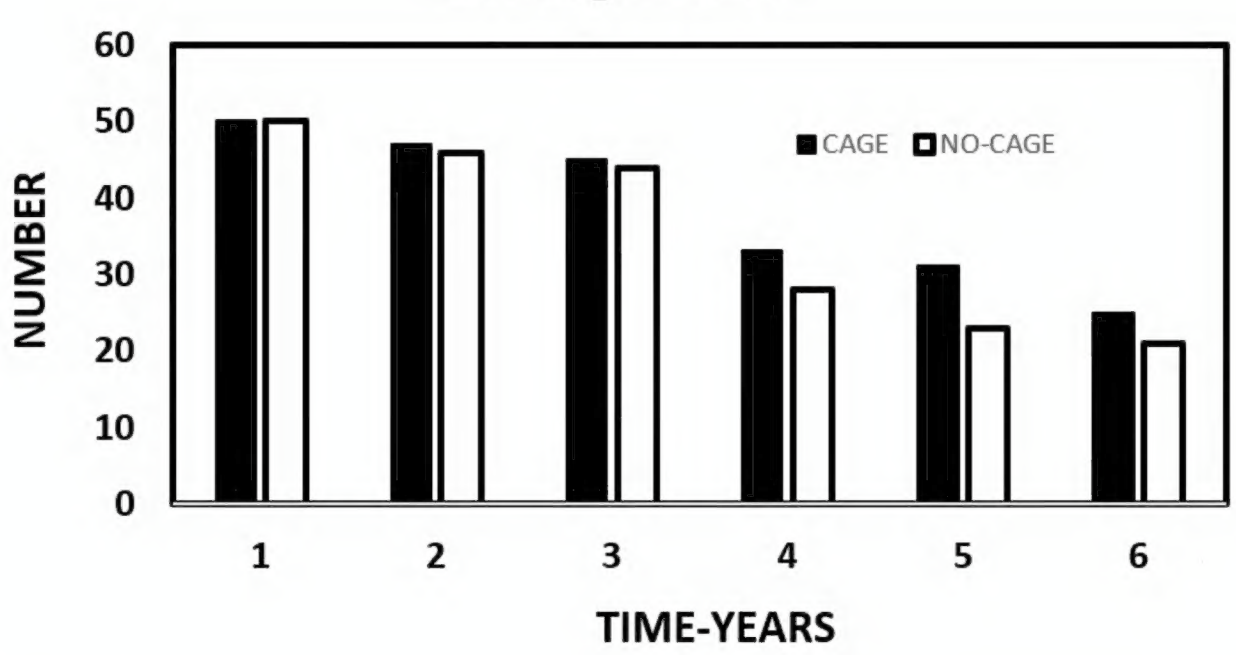


Figure 5. Survival of *Juniperus ashei* seedlings at Albert and Bessie Kronkosky State Natural Area from the beginning to the end of the study (September 2023). In the open (no-cage) there were 29 total mortalities while in the caged or protected treatment there were 25 mortalities There was no difference in mortality between caged (protected) and non-caged (non-protected) treatments ($X^2$=0.645, $P$ = 0.422).

## DISCUSSION

Some studies examined the relationship between *Juniperus ashei* seedling mortality and multiple variables including light, rainfall, and soil moisture (Jackson and Van Auken 1997; Van Auken et al. 2004; McKinley and Van Auken 2005). However, most literature observations were antidotal concerning herbivory. That is, the studies did not have protected plants. *Juniperus ashei* and other *Juniperus* herbivory studies showing some browsing of mature individuals (Bryant et al. 1981; Warren 1983; Fuhlendorf et al. 1997; Armstrong and Young 2002; Cadenasso et al. 2002;). Recruitment of seedlings of *J. ashei* into the mature or adult population has been demonstrated (Van Auken et al. 2023) but was occurring in open, disturbed areas adjacent to mature canopy trees. *Juniperus ashei* seedlings may be more palatable than mature leaves and branches, but has not yet been demonstrated. Identifying the relationship between *J. ashei* seedling mortality and large mammal herbivory will contribute to the understanding of *J. ashei* growth development and may influence *J. ashei* management.

In this study, *Juniperus ashei* seedlings were observed for differences in mortality of those protected from herbivory (caged) or not protected (not caged). There was no apparent difference between those protected from herbivory or not protected. *Juniperus ashei* composes a small portion of *O. virginianus*

browsing (Bryant et al. 1981; Warren 1983). This observation may indicate potential *J. ashei* seedling browsing if the range conditions are poor. One of the studies demonstrated that browsed *J. ashei* foliage was less digestible than other browsed samples (Adams et al. 2013). *Juniperus ashei* seedling digestibility measures may help clarify if seedlings are more palatable than leaves of mature trees. An example of when *J. ashei* seedlings may be favored over mature *J. ashei* trees is when there is no mature green foliage below the browse line. In another study observing *J. ashei* seedlings, stated that there was little to no apparent seedling mortality related to deer herbivory (Jackson and Van Auken 1997). That study was conducted at Eisenhower Park in a more urbanized region with fewer *O. virginianus*.

The current study site may be limited because the natural area has managed wildlife populations. There may be different results in an area with a higher population density of *O. virginianus* or other large herbivores, such as *Odocoileus hemionus* (mule deer), or exotic game species such as *Axis axis* (axis) and *Oryx dammah* (oryx), or possibly domestic goats (Bovidae, *Capra* sp. that have been used for range improvement by removing woody vegetation including juvenile *Juniperus* plants [Scifres 1980]). However, there were no goats in the ABK State Natural Area. Future studies should observe additional cohorts in other sites with different environmental characteristics and properties. The current study contributes to understanding the relationship between *J. ashei* seedlings recruitment and herbivory and to the understanding of community dynamics.

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